TACTILE DISPLAY DEVICE AND TOUCH PANEL APPARATUS WITH TACTILE DISPLAY FUNCTION

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a tactile display device for displaying tactile information and further relates to a touch panel apparatus with such a tactile display device.

[0003] 2. Description of the Related Art

[0004] As such a tactile display method, there is presented a method of controlling an appearance of a convex key by means of an electrorheological fluid (ER fluid), for example (Japanese Patent Application Laid-Open No. Hei 11-273501).

[0005] In this method, the electrorheological fluid is sealed within a plate-like receptacle or box disposed above a display device. Then, an electrical power distribution over this fluid is controlled in such a manner that a part or area of the electrorheological fluid (i.e. the fluid which viscosity is changed by electricity) corresponding to the convex key is relieved or embossed by means of a pump as a pressure device. As a result, an embossed key can be appeared.

[0006] Furthermore, there is also presented a technology for applying a counterforce to a display element in response to a deformation, by means of an electrorheological fluid (Japanese Patent Application Laid-Open No. 2000-89895 and so on).

[0007] However, the aforementioned related arts have a problem as described below.

[0008] In order to change the viscosity of the electrorheological fluid, it is necessary to control voltage which is applied to the electrorheological fluid, in accordance with "a pattern to be displayed" (hereinafter referred to as a "display pattern" as appropriate) and the like. Therefore, a special device for performing such a control is required, which increases a size of the apparatus and/or causes heavy-duty operation. That is, from a technical viewpoint, it is difficult to display the tactile information efficiently.

SUMMARY OF THE INVENTION

[0009] The present invention has been accomplished in view of the aforementioned problem, for example. It is therefore an object of the present invention to provide a tactile display device for displaying the tactile information effectively. It is a further object of the present invention to present a touch panel apparatus with tactile display function having such a tactile display device.

[0010] (Tactile Display Device)

[0011] The above object of the present invention is achieved by a tactile display device disposed on a display screen for outputting display light corresponding to a display pattern, said tactile display device comprising: a pair of electrodes having a light transmissive property and disposed opposite to the display screen; a characteristic change layer disposed between said pair of electrodes, said characteristic change layer having a light transmissive property, wherein at least one of conductivity and magnetic permeability of said characteristic change layer changes at each part on the display screen in response to intensity of the display light; and an electrorheological fluid layer disposed between said pair of electrodes and opposite to said characteristic change layer, said electrorheological fluid layer having a light transmissive property, wherein viscosity of said electrorheological fluid layer changes at each part on the display screen in response to applied voltage applied through said characteristic change layer by said pair of electrodes.

[0012] According to the tactile display device of the invention, electric voltage is applied between a pair of electrodes during the operation. A portion of this electric voltage is applied to the electrorheological fluid layer. The "electrorheological fluid" herein means a fluid having a property of changing its viscosity in response to the applied voltage. If the applied voltage for the electrorheological fluid layer is changed in accordance with a pattern to be displayed, the viscosity can be increased (i.e. become harder) in the inside of the pattern, and decreased (i.e. become softer) in the remaining area. Therefore, the operator can feel tactily a shape or outline of the pattern. That is, the tactile information can be presented.

[0013] Specifically, an effort to control the viscosity of the electrorheological fluid by controlling the applied voltage for each pixel composing a certain pattern may cause the aforementioned problem as seen in the related arts. That is, the ineffectively heavy-duty operation reduces the efficiency.

[0014] Nevertheless, in the tactile display device of the present invention, such a problem is solved by disposing the characteristic change layer opposite to the electrorheological fluid layer.

[0015] The "characteristic change layer" herein means a layer made of a material having a property of changing at least one of the conductivity and the magnetic permeability in response to the intensity of the irradiation light. If the intensity of the irradiation light is changed relative to the characteristic change layer in accordance with the display pattern, at least one of the conductivity and the magnetic permeability of this characteristic change layer changes in accordance with the display pattern. This change in or of the conductivity or the magnetic permeability causes a change in or of partial pressure applied to the electrorheological fluid, as well as a viscosity change (i.e. a change of a viscosity) of the electrorheological fluid layer. For example, it is possible to harden (or soften) a part of the electrorheological fluid layer with the higher intensity of the irradiation light and soften (or harden) a part of the electrorheological fluid layer with the lower intensity of the irradiation light. That is, the tactile information as described above can be presented.

[0016] Furthermore, since the pair of electrodes, the characteristic change layer and the electrorheological fluid layer have the light transmissive property, respectively, the change in or of the intensity of the irradiation light is represented by the visual information presented to the operator through these layers, that is, represented by the change in or of the display light outputted in accordance with the display pattern displayed on the display screen. For example, if the display pattern displayed on the display screen is of a binary pattern made of black and white, the display light for the white part represents the higher intensity of the irradiation light, and the display light for the black part (including a